

# A new genus from Vietnam (Hymenoptera, Braconidae, Opiinae), and the description of two new species

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## Abstract

Two aberrant species of Opiinae are described and illustrated from Vietnam, of which one is included into a new genus (*Canalopius* **gen. n.**; type species: *C. periscopus* **sp. n.**). The other species, *Xynobius chrysops* **sp. n.** belongs to an aberrant group of species near *X. maculipennis* (Enderlein, 1912).

## Keywords

Braconidae, Opiinae, *Canalopius*, *Xynobius*, new genus, new species, Oriental, Vietnam

## Introduction

The large subfamily Opiinae (Braconidae), with 2,060+ valid species (Yu et al. 2016), is a common group of parasitoid wasps. It has a worldwide distribution and the world fauna has been reviewed by Fischer (1972, 1977, 1986, 1987) with most species dumped into one genus (*Opius* Wesmael, 1835 *sensu lato*). The number of genera and the limits of several genera are still a matter of discussion, despite updates by Wharton (1988, 1997), van Achterberg (1997, 2004a, 2004b), van Achterberg and Salvo (1997), van Achterberg and Chen (2004), and Li et al. (2013). Currently about 39 genera are used, with about 60 additional names circulating in the existing literature;

mostly as subgenera in the genus *Opius* Wesmael *s.l.* Recently, 28 subgenera were synonymized in Li et al. (2013).

*Xynobius* is a fairly large genus, of which many described species remain wrongly classified in *Opius*. Another problem is the undercollecting of this group; we have seen many new species from the Palaearctic and Oriental regions in the few recently made collections. One of these collections is from Vietnam assembled by a joint effort of Naturalis Biodiversity Center (RMNH, Leiden) and the Institute of Ecology & Biological Resources (IEBR, Hanoi). During a short visit to Leiden the first author sorted the two highly aberrant species of Opiinae described in this paper.

Opiinae are solitary koinobiont endoparasitoids of dipteran larvae. The parasitoid larva has its final development when the host larva has made its puparium; after pupation the adult wasp emerges from this puparium (Shaw and Huddleston 1991).

## Material and methods

The material examined is deposited in the collection of Naturalis Biodiversity Center (RMNH) at Leiden. The specimens were collected in alcohol 70% using Malaise traps and the specimens were later prepared with the AXA method (van Achterberg 2009) and card-pointed.

For identification of the subfamily Opiinae, see van Achterberg (1990, 1993), for identification of the genera, see Wharton (1997, 2009), Chen and Weng (2005), Li et al. (2013), Tan et al. (2016) and the diagnosis of the new genus in this paper. For references to the biology, see Yu et al. (2016) and for the morphological terminology used in this paper, see van Achterberg (1988, 1993), including the abbreviations for the wing venation. Measurements are taken as indicated by van Achterberg (1988): for the length and the width of a body part the maximum length and width is taken, unless otherwise indicated. The length of the mesosoma is measured from the anterior border of the mesoscutum till the apex of the propodeum and of the first tergite from the posterior border of the adductor till the medio-posterior margin of the tergite.

Descriptions and measurements were made under a stereomicroscope (Zeiss Stemi SV 6). Photographs were made with a Keyence VHX-2000 digital microscope.

## Taxonomy

### *Canalopius* Wu & van Achterberg, gen. n.

<http://zoobank.org/13A7B5E2-9667-4B03-9067-4BAC30CA5B27>

Figs 1–11

**Type species.** *Canalopius periscopus* sp. n.

**Etymology.** From “canalis” (Latin for “groove, channel”) and the generic name *Opius*, because of the channel-like groove of the occiput. Gender: masculine.

**Diagnosis.** Vertex and occiput with very deep medial groove up to between posterior ocelli; vertex depressed near posterior ocelli; stemmaticum reversed “Y”- shaped, abruptly protruding and with anterior ocellus on anterior branch far above frons (Figs 1b–e, 5, 8); anterior ocellus close to level of antennal sockets and distance between anterior ocellus and posterior ocellus nearly twice distance between posterior ocelli; anterior ocellus on protruding crest; occipital carina entirely absent; mandible slightly twisted, its basal half dorsally and ventrally with fine carina, nearly straight ventrally, apically gradually narrowed and with second teeth much smaller than first tooth (Figs 2, 4); precoxal sulcus present medially; medio-posterior depression of mesoscutum absent; dorsal surface of propodeum narrow, coarsely crenulate in front of curved carina, and medio-longitudinal carina complete; vein 2-SR of fore wing present; base of hind tibia without carinula at inner side and setose; legs robust (Fig. 1a); dorsope absent; second slightly shorter than third tergite and both smooth; ovipositor sheath short, hardly protruding.

**Distribution.** Oriental (Vietnam).

**Biology.** Unknown.

**Notes.** The new genus will run in the key to world genera by Wharton (1997) and the key to Chinese genera by Chen and Weng (2005) to the genus *Opius* Wesmael, 1835; in the key by Fischer (1972) it ends up at *Desmiostoma* Foerster, 1863, because of the absence of an occipital carina. In Li et al. (2013) it runs to *Rhogadopsis* Brèthes, 1913, because of the venation and the medio-longitudinal carina of the propodeum. The new genus can be separated from all known genera as follows:

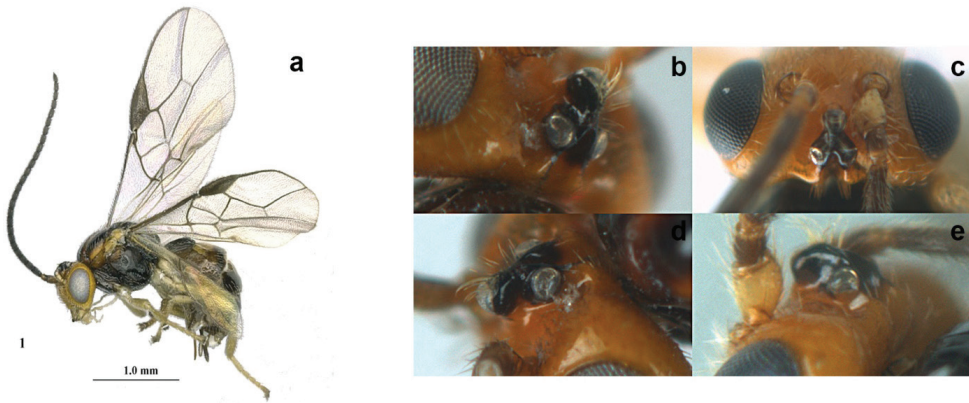
- 1 Anterior ocellus close to level of antennal sockets and distance between anterior ocellus and posterior ocellus nearly twice distance between posterior ocelli; anterior ocellus on protruding crest; occiput with deep median groove; occipital carina absent laterally; transverse carina of propodeum present .....  
..... ***Canalopius* Wu & van Achterberg, gen. n.**
- Anterior ocellus distinctly removed from level of antennal sockets and distance between anterior ocellus and posterior ocellus similar to distance between posterior ocelli; anterior ocellus without crest; occiput without median groove; occipital carina usually present laterally, if absent (*Desmiostoma* and some *Opius* spp.) then also transverse carina of propodeum lacking .....  
..... **other genera of Opiinae**

***Canalopius periscopus* Wu & van Achterberg, sp. n.**

<http://zoobank.org/4090EEFF-66E0-491E-BDFD-C315FC2817AD>

Figs 1–11

**Type material.** Holotype, ♀ (RMNH), “N. Vietnam: Hoa Binh, Pa Co Hang Kia N.R., 20°44'35"N, 104°56'22"E, 1030 m, 9–23.x.2009, Mal[aise] tr[ap] 2, C. van Achterberg & R. de Vries”. Paratypes: 1 ♀ (IEBR), “S. Vietnam: Dak Lak, Chu Yang Sin



**Figure 1.** *Canaloapius periscopus* sp. n., ♀, holotype. **a** habitus, lateral aspect **b–e** stemmaticum and median furrow of vertex at different angles.

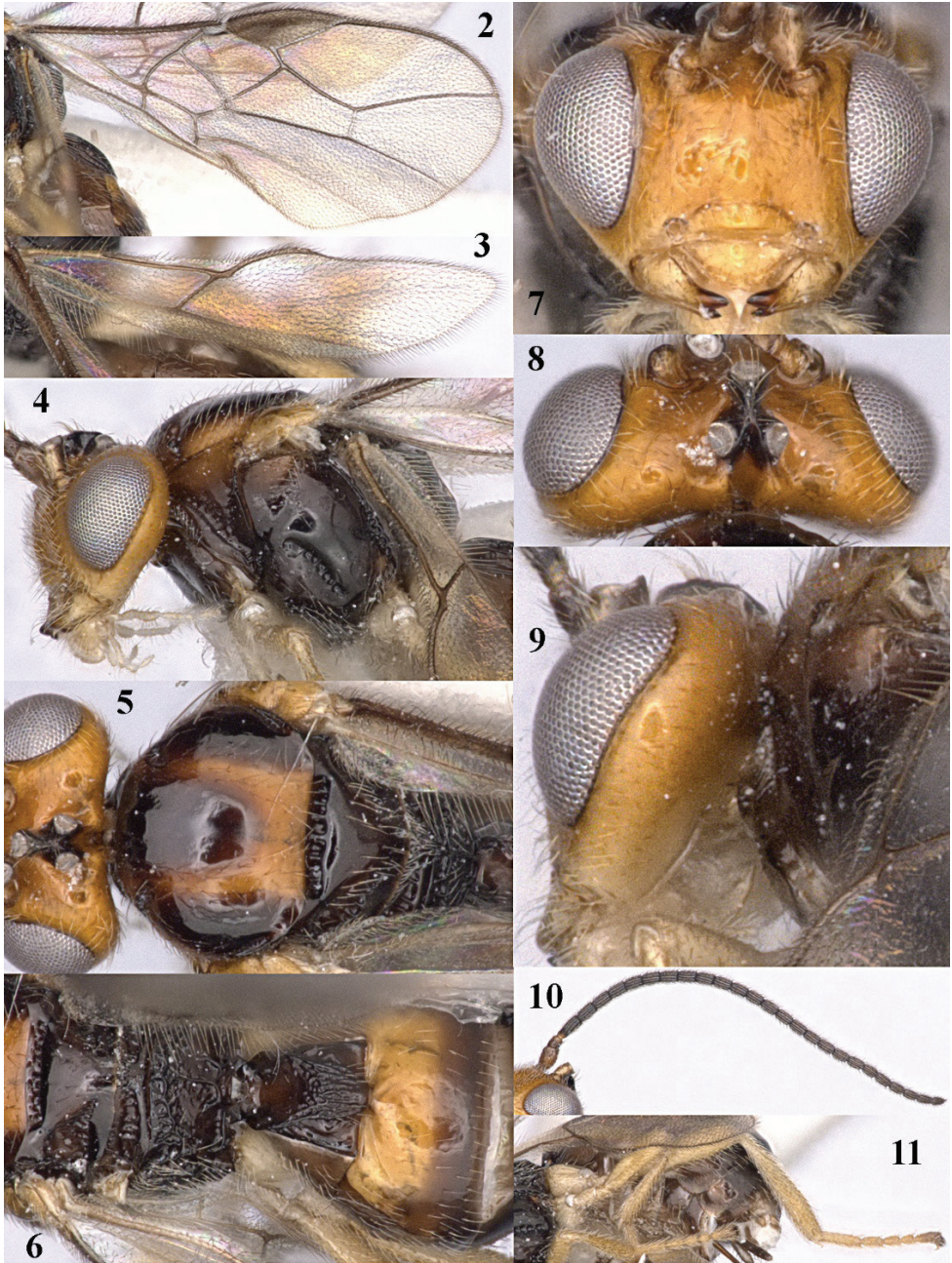
N.P., n[ea]r dam, 800–940 m, 2–10.vi.2007, Mal[aise] traps, C. van Achterberg & R. de Vries, RMNH'07"; 1 ♂ (RMNH), same data as paratype, but c. 500 m, 3–9.vi.2007.

**Description.** Holotype, ♀, length of body 2.8 mm, of fore wing 2.6 mm.

**Head.** Antenna with 27 segments, bristly setose and 1.05 times as long as fore wing; third segment 1.3 times as long as fourth segment, length of third, fourth and penultimate segments 2.7, 2.0 and 2.0 times their width, respectively (Fig. 10); length of maxillary palp 0.9 times height of head (Fig. 4); length of eye in dorsal view 2.6 times temple (Fig. 8); temple and vertex shiny, smooth, and with sparse setae; occiput and vertex medially with very deep vertical furrow up to between posterior ocelli; vertex depressed near posterior ocelli; stemmaticum reversed “Y”- shaped and abruptly protruding dorsally, with long setae dorsally and with anterior ocellus on anterior branch far above frons (Figs 1b–e, 5, 8); OOL: diameter of ocellus: POL= 13:4:3; occipital carina absent; hypostomal carina narrow (Fig. 9); face smooth and sparsely setose (Fig. 7); frons smooth behind antennal sockets; labrum glabrous and smooth, slightly depressed; clypeus transverse, smooth, convex, and its ventral margin truncate (Fig. 7); width of clypeus 3.4 times its maximum height and 0.5 times width of face; hypoclypeal depression rather large (Fig. 7); mandible slightly twisted, its basal half dorsally and ventrally with fine carina, nearly straight ventrally, apically gradually narrowed and with second teeth much smaller than first tooth (Figs 2, 4); malar suture absent; malar space 0.5 times as long as basal width of mandible.

**Mesosoma.** Length of mesosoma 1.4 times its height; dorsal pronope round and rather large, filled with white tissue; pronotal side largely smooth, but crenulate dorso-anteriorly and posteriorly (Fig. 4); propleuron flattened and largely glabrous except apically; epicnemial area smooth; precoxal sulcus medium-sized, moderately crenulate and distinctly impressed, but absent anteriorly and posteriorly (Fig. 4); remainder of mesopleuron smooth and shiny, sparsely setose antero-dorsally and postero-ventrally; only ventral half of pleural sulcus distinctly crenulate; mesosternum densely setose;





**Figures 2–11.** *Canalopius periscopus* sp. n., ♀, holotype. **2** fore wing **3** hind wing **4** head and mesosoma, lateral aspect **5** head and mesosoma, dorsal aspect **6** propodeum and first third metasomal tergites, dorsal aspect **7** head, anterior aspect **8** head, dorsal aspect **9** head, lateral aspect **10** antenna **11** hind leg, lateral aspect.

mesosternal sulcus deep, medium-sized and crenulate; postpectal carina absent; anterior groove of metapleuron largely smooth except a few crenulae; mesoscutum very shiny, smooth and with band of setae indicating imaginary course of notauli (Fig. 5); notauli only present basally and absent on disc; medio-posterior depression of mesoscutum absent; scutellar sulcus deep and with 7 short crenulae, parallel-sided; scutellum flattened and smooth, (Figs 5, 6); lateral axillar lamella narrow; dorsal surface of propodeum coarsely crenulate and narrow, posteriorly bordered by curved carina, medio-longitudinal carina complete, with some short rugae medio-dorsally, and remainder largely smooth (Fig. 6).

*Wings.* Fore wing: 1-SR 0.6 times longer than 1-M (Fig. 2); pterostigma wide triangular; 1-R1 ending at wing apex and 1.4 times as long as pterostigma; r long and linear with 3-SR with obtuse angle; r-m not tubular; r:3-SR:SR1 = 7:32:58; 2-SR:3-SR:r-m = 15:32:16; 1-M curved and SR1 nearly straight; m-cu distinctly postfurcal and straight; cu-a slightly postfurcal, nearly interstitial, and 1-CU1 widened; 1-CU1:2-CU1 = 3:31; first subdiscal cell closed; CU1b medium-sized; M+CU1 unsclerotized. Hind wing: 1-M of hind wing straight, resulting in subparallel-sided cell apically; M+CU:1-M:1r-m = 12:10:7; cu-a straight; SR absent (Fig. 3).

*Legs.* Length of femur, tibia and basitarsus of hind leg 3.7, 7.8 and 2.7 times as long as width, respectively (Fig. 11); femur moderately setose, tarsus and tibia densely setose.

*Metasoma.* Length of first tergite 1.1 times its apical width, convex and irregularly rugose medio-posteriorly and remainder largely smooth (Fig. 6), dorsal carinae strong basally and reaching apex of tergite, dorsope absent; second suture almost invisible; basal depressions of second tergite shallow, wide and oblique, and second tergite 0.8 times as long as third tergite; second and following tergites smooth, shiny and with row of setae posteriorly; combined length of second and third metasomal tergites 0.3 times total length of metasoma; setose part of ovipositor sheath 0.1 times as long as fore wing (entire visible sheath 0.14 times), 0.5 times first tergite (entire sheath 0.9 times) and 0.3 times hind tibia (entire sheath 0.4 times); hypopygium nearly 0.2 times as long as metasoma, truncate apically and not reaching apex of metasoma (Fig. 11).

*Colour.* Dark brown; head (but teeth of mandible dark brown and stemmaticum black), scape ventrally, tegulae, mesoscutum laterally and imaginary courses of notauli and second tergite dorsally brownish yellow; scape dorsally, pedicellus ventrally, pronotal side dorsally and mesopleuron dorsally brown; pterostigma, veins, remainder of metasoma and ovipositor sheath largely dark brown; palpi, mandible, and legs pale yellowish (but telotarsus brown); fore wing membrane subhyaline.

*Variation.* Length of fore wing 2.0–2.6 mm, of body 2.1–2.8 mm; antennal segments 25 (1 ♂) or 27 (1 ♀), length of first tergite 1.1–1.3 times its apical width; mesosoma of male entirely black, of female paratype mesoscutum, scutellum, prothorax and dorsal half of mesopleuron brownish yellow.

**Distribution.** Vietnam.

**Biology.** Unknown.

**Etymology.** Name is derived from “peri” (Greek for “around”) and “skopos” (Greek for “watcher”) because the anterior ocellus is protruding from the head like a periscope.

**Genus *Xynobius* Foerster, 1863**

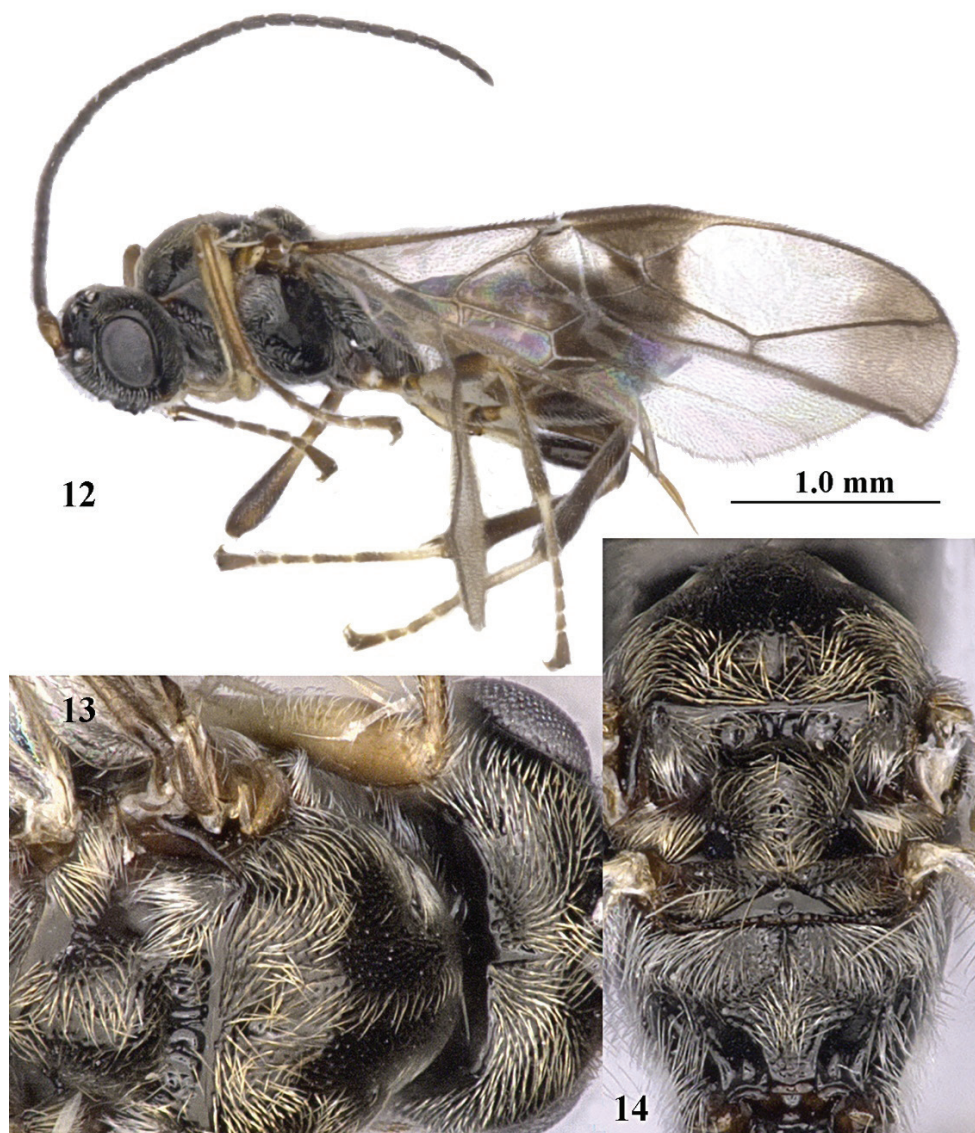
Figs 12–23

- Xynobius* Foerster, 1863: 235; Li et al. 2013: 171. Type species (by original designation): *Xynobius pallipes* Foerster, 1863 (= *Opius caelatus* Haliday, 1837) [examined].
- Aclisis* Foerster, 1863: 267; Fischer 1972: 68 (as synonym of *Opius* Wesmael, 1835); van Achterberg 2004a: 315 (as synonym of *Xynobius* Foerster, 1863). Type species (by original designation): *Aclisis isomera* Foerster, 1863 (= *Opius caelatus* Haliday, 1837) [examined].
- Holconotus* Foerster, 1863: 259 (not Schmidt-Göbel, 1846); Fischer 1972: 67, 102; van Achterberg 2004a: 315 (as synonym of *Xynobius* Foerster, 1863). Type species (by original designation): *Opius comatus* Wesmael, 1835) [examined].
- Aulonotus* Ashmead, 1900: 368 (new name for *Holconotus* Foerster, 1863); Fischer 1972: 68, 102 (as subgenus of *Opius* Wesmael, 1835); van Achterberg 2004a: 315 (as synonym of *Xynobius* Foerster, 1863). Type species (by original designation): *Opius comatus* Wesmael, 1835) [examined].
- Eristerناولax* Viereck, 1913: 362; Fischer 1972: 68 (as synonym of *Opius* Wesmael, 1835, 102 (as synonym of subgenus *Aulonotus* Ashmead, 1900); van Achterberg 2004a: 315 (as synonym of *Xynobius* Foerster, 1863). Type species (by original designation): *Eristerناولax leucotaenia* Viereck, 1914) [examined].
- Stigmatopoea* Fischer, 1986: 610, 611 (as subgenus of *Opius* Wesmael, 1835), 1998: 25 (key to species); Wharton 1988: 356; 2006: 338 (as subgenus of *Eurytenes* Foerster, 1863; possible paraphyly in *Xynobius*); van Achterberg 2004a: 315 (as synonym of *Xynobius* Foerster, 1863). Type species (by original designation): *Opius macrocerus* Thomson, 1895 [examined].
- Xynobiotenes* Fischer, 1998: 23 (as subgenus of *Eurytenes* Foerster, 1863); Li et al. 2013: 171 (as synonym of *Xynobius* Foerster, 1863). Type species (by original designation): *Opius scutellatus* Fischer, 1962 [examined].

**Diagnosis** (modified after Li et al. 2013). Hypoclypeal depression present, often large, and medially ventral margin of clypeus above upper level of condyli of mandibles (“subcyclostome condition”) or near it (Fig. 20), rarely hypoclypeal depression nearly absent; occipital carina widely to narrowly interrupted dorsally or nearly contiguous (Fig. 18); mandible simple basally, at most with a narrow ventral carina (Fig. 20); notauli variable; medio-posterior depression of mesoscutum present (Fig. 14); precoxal sulcus present, smooth or crenulate, no indication of sternaulus; vein m-cu of fore wing usually (sub) parallel to vein 1-M (Fig. 12); vein r more or less angled with vein 3-SR of fore wing and distinctly shorter than vein 2-SR (Fig. 15); vein 3-SR distinctly longer than vein 2-SR; pterostigma long and narrow and more or less widened towards its apex, elliptical or triangular (Fig. 15); dorsope present, often bordered by lamelliform carinae (Fig. 19); second metasomal tergite striate or smooth; hypopygium of ♀ at most slightly incised.

**Biology.** Koinobiont endoparasitoids of leaf miners of Anthomyiidae, Tephritidae and Scathophagidae (Yu et al. 2016).





**Figures 12–14.** *Xynobius chrysops* sp. n., ♀, holotype. **12** habitus, lateral aspect **13** scutellum and posterior half of mesoscutum, dorsal aspect **14** metanotum and propodeum, dorsal aspect.

**Notes.** Wharton (1988) treated *Xynobius* as a synonym of the genus *Opius* Wesmael, 1837, but it has a distinct dorsope and according to the limited available molecular data (Li et al. 2013) it is not closely related to *Opius* s.s. as treated by Li et al. (2013). Part of it (the subgenus *Stigmatopoea* Fischer, 1986) has been included by Fischer (1998) and Weng and Chen (2005) in the genus *Eurytenes* Foerster, 1863, but it seems to fit better in *Xynobius* (van Achterberg 2004a; Li et al. 2013). Wharton (2006) and Walker and Wharton (2011) placed *Xynobius* as a subgenus of *Eurytenes*, but we prefer to keep them separated till more is known about their relationships.



***Xynobius chrysops* sp. n.**

<http://zoobank.org/024E09B3-B558-42F0-AADC-B671EF6CD9D8>

Figs 12–23

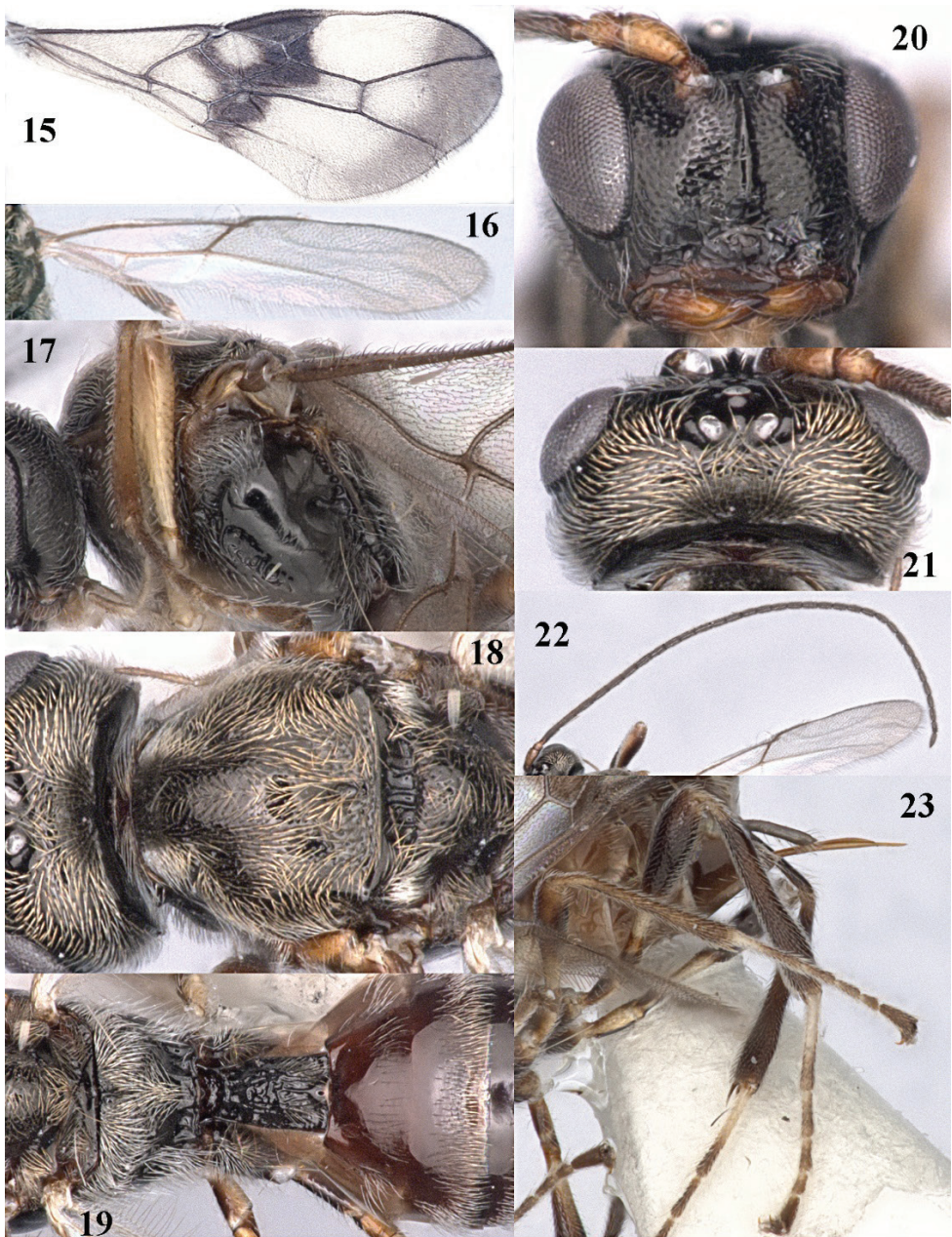
**Type material.** Holotype, ♀ (RMNH), “NW. **Vietnam:** Tonkin, Hoang Lien N.R., 15 km W [of] Sa Pa, c. 1900 m, 15–21.x.1999, Malaise traps, C. v. Achterberg, RMNH’99”.

**Description.** Holotype, ♀, length of body 3.3 mm, of fore wing 3.6 mm.

*Head.* Antenna with 35 segments, bristly setose and 1.3 times as long as fore wing; third segment 1.1 times as long as fourth segment, length of third, fourth and penultimate segments 5.0, 4.5 and 2.3 times their width, respectively (Figs 12, 22); length of maxillary palp 1.2 times height of head; length of eye in dorsal view as long as temple (Fig. 21); temple in dorsal view shiny, smooth, temple and vertex with adpressed setae; OOL: diameter of ocellus: POL = 1:1:3; face sparsely punctate, with a medio-longitudinal ridge extending to level of antennal sockets (Fig. 20); frons glabrous behind antennal sockets; in front of anterior ocellus shiny, smooth and glabrous but laterally setose (Fig. 20); labrum invisible; clypeus nearly semi-circular, with some oblique striae, convex but flattened ventrally, and its ventral margin truncate and narrow (Fig. 20); clypeus 2.1 times wider than its maximum height and 0.6 times wider than face; hypoclypeal depression narrow, slit-shaped; mandible straight ventrally, hardly twisted, apically gradually narrowed and second tooth small; mandible and with narrow ventral carina (Fig. 20); occipital carina remains far removed from hypostomal carina ventrally and horizontal dorsally, narrowly interrupted medio-dorsally; hypostomal carina narrow; malar suture distinct, narrow; length of malar space 0.9 times basal width of mandible.

*Mesosoma.* Length of mesosoma 1.5 times its height; dorsal pronope minute, round, (Figs 18, 21); pronotal side largely smooth, but crenulate dorso-anteriorly and densely setose anteriorly and posteriorly (Figs 12, 17); propleuron slightly convex, finely punctate and setose; epicnemial area densely setose dorsally, finely crenulate in groove ventrally; only anterior half of precoxal sulcus present, medium-sized and distinctly crenulate (Fig. 17); remainder of mesopleuron smooth and shiny; pleural sulcus distinctly crenulate; mesosternal sulcus moderately deep, narrow and crenulate; postpectal carina absent; mesoscutum very shiny, finely punctate, with golden setae and smooth interspaces (Figs 13, 18); notauli only anteriorly impressed, deep, narrow and crenulate and largely absent on disc; medio-posterior depression of mesoscutum droplet-shaped (Fig. 13); scutellar sulcus deep and with 4 short crenulae, parallel-sided medially; scutellum convex and smooth, finely punctate and densely setose (Fig. 14); side of scutellum and axilla densely golden setose, and lateral axillar lamella very wide (Figs 13, 14); metanotum glabrous medially and densely setose laterally; antero-dorsal part of propodeum densely setose, rugose near transverse ridge and with medio-longitudinal carina; posterior part of propodeum largely smooth, and with 4 long and curved carinae (Fig. 14).

*Wings.* Fore wing: 1-SR distinctly longer than wide and nearly linear with 1-M (Fig. 15); pterostigma wide triangular; 1-R1 ending at wing apex and twice as long as



**Figures 15–23.** *Xynobius chrysops* sp. n., ♀, holotype. **15** fore wing **16** hind wing **17** mesosoma, lateral aspect **18** head and mesosoma, dorsal aspect **19** propodeum and first-third metasomal tergites, dorsal aspect **20** head, anterior aspect **21** head, dorsal aspect **22** antenna **23** hind leg, lateral aspect.

pterostigma; r long and connected with 3-SR by obtuse angle;  $r:3\text{-SR}:SR1 = 6:33:58$ ;  $2\text{-SR}:3\text{-SR}:r\text{-m} = 8:11:4$ ; 1-M slightly curved and SR1 straight; m-cu distinctly postfurcal and straight; cu-a distinctly postfurcal and 1-CU1 slightly widened;  $1\text{-CU1}:2\text{-CU1} = 1:18$ ; first subdiscal cell closed and CU1b medium-sized; entire  $M+CU1$  sclerite

rotized (Fig. 17). Hind wing: 1-M of hind wing straight, resulting in subparallel-sided cell apically; M+CU:1-M:1r-m = 30:34:15; cu-a straight; m-cu unsclerotized, spectral; SR absent (Fig. 16).

*Legs.* Length of femur, tibia and basitarsus of hind leg 4.1, 7.8 and 9.0 times as long as width, respectively (Fig. 23); femur with long setae, tarsus and tibia densely setose; hind tibia slender medially; dorsally hind tibia with large smooth and glabrous patch subbasally (Fig. 23).

*Metasoma.* Length of first tergite 1.7 times to its apical width, convex, its surface irregularly rugose medially (Fig. 19), dorsal carinae strong and combined in its basal third and area below widely depressed, but dorsope small; second suture almost invisible; basal depressions of second tergite minute and tergite as long as third tergite, both with wide setose bands (Fig. 19); second and following tergites smooth, shiny and setose posteriorly, especially densely in third tergite; combined length of second and third metasomal tergites 0.4 times total length of metasoma; setose part of ovipositor sheath 0.07 times as long as fore wing (exposed sheath 0.11 times), 0.6 times first tergite (entire sheath as long as tergite), and 0.2 times hind tibia (entire sheath 0.4 times); hypopygium about 0.3 times as long as metasoma, truncate apically and not reaching apex of metasoma (Fig. 23).

*Colour.* Blackish brown, but scape, pedicellus, mandible (but teeth dark), tegulae, fore coxa dorsally, fore femur laterally and ventrally, fore tibia basally, trochantellus dorsally, second tergite laterally yellowish brown; ventral margin of clypeus, pterostigma and veins, markings of fore wing near veins r, 1-SR+M, 2-SR, basal half of 3-SR, m-cu, basal of second discal cell and second subdiscal cell, fore femur dorsally, trochanter dorsally, tarsus (but pale basally), second tergite medially and following tergites dark brown; palpi, inner side of fore coxae, trochanter ventrally, middle and hind tibia basally pale yellowish; setae on vertex, temple, mesoscutum, scutellum, side of scutellum and metanotum golden, remainder of setae silvery; remainder of fore wing membrane subhyaline.

**Distribution.** Vietnam.

**Biology.** Unknown.

**Notes.** This aberrantly coloured new species belongs to a small group of Asian spp. near *Xynobius maculipennis* (Enderlein, 1912) united by the subbasally widened hind tibia with the resulting small knob glabrous and shiny dorsally, the hypopygium dark brown, the head and mesoscutum densely pubescent, and the fore wing with a large Y-shaped dark brown area below para- and pterostigma (Fig. 15). The new species differs from all other species examined by having the third metasomal tergite with a wide band of setae apically (Fig. 19; narrow in other species); fore wing infusate apically (Fig. 15; subhyaline); the hypoclypeal depression nearly absent (distinct); the head and mesosoma dark golden pubescent combined with a slender first tergite (slightly widened apically and  $1.6 \times$  longer than its apical width; other species have usually pale yellowish or silvery pubescence, if dark golden than first tergite 1.2–1.3 times as long as wide apically).

**Etymology.** Named after the partly golden setosity; “chrysops” is Greek for “gold-coloured”.



## Acknowledgements

The field work was only possible because of the excellent help of staff of IEBR (Hanoi), in particular of Dr Khuat Dang Long. The second author received financial support from the Uyttenboogaart-Eliassen Stichting (Amsterdam) for research in Vietnam. The research was supported jointly by the State Key Program of National Natural Science Foundation of China (No. 31702035).

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